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Calibration methods for in-situ micrometeorite sensors

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Investigating the dynamical and physical properties of cosmic dust can reveal a great deal of information about both the dust and its many sources. Over recent years several spacecraft (e.g. Cassini, Stardust, Galileo) have successfully characterised interstellar, interplanetary and circumplanetary dust using a variety of techniques.

In situ measurements, the direct interception and analysis of dust particles by spacecraft-based instrumentation, allows us to gain insights into the dynamical, physical and chemical properties of solar system dust.
Several methods have been used to investigate these characteristics, i.e. thin-foil penetration, impact flash detection, or inductive measurement of the particle charge.

The methods yielding the highest sensitivity for detection of dust particles in space, rely on impact ionisation: when a dust particle impacts onto a solid target, parts of the impactor and the target are vaporised and ionised by the energy released during the impact. This leads to the formation of an impact plasma, expanding rapidly into the surrounding vacuum. The constituents of the plasma are separated due to an electrostatic field depending on their polarity, accelerated towards either an ion detector or the target plane, and are then amplified and recorded.

With suitable charge detectors and instrument geometry, impact ionisation sensors can act as highly sensitive TOF mass spectrometers. Use of a field-free drift region enables the accelerated ions to be separated in mass and sequentially recorded. Thus the flight times for different ion species can be determined and the charge intensities then calibrated onto a mass scale. Depending on the exact instrument field geometry, and the properties of the impact, the chemical composition of the impacting particle can be determined. The advantages of such detectors are their simplicity and the possibility of simultaneous measurements of the dynamical properties of the particle and its chemical composition.
The accurate and reliable interpretation of collected spacecraft data requires a comprehensive programme of terrestrial instrument calibration. This process involves accelerating suitable solar system analogue dust particles to hypervelocity speeds in the laboratory, an activity performed at the MPI for nuclear physics in Heidelberg, Germany. Here a 2 MV Van de Graaff accelerator electrostatically accelerates charged micron and submicron-sized dust particles to speeds in excess of 80 km/s.

To cover a sufficiently big energy range for the investigation of dust particle impacts and the calibration of impact ionisation instruments, we attempted to complement the particle impact experiments with laser ionisation. Therefore it was necessary to investigate the properties of both processes with respect to their comparability. For this, the characteristics of the emerging plasma, such as the velocity distribution of the ions, and the ion appearance in the TOF mass spectra are analysed and compared. The findings of this study show that, in general, laser ionisation plasma is not comparable to that generated by hypervelocity particle impacts. However, particular aspects of the the laser ionisation process can be used as a rough substitute for particle impacts, i.e. optimising and testing electronic components for impact ionisation instruments.
Furthermore, the dependence of the plasma properties on the impact parameters were studied. Here, the experimental results imply that the defining parameter of the impact process is either the impact velocity or the energy density.